

HOW IT WORKS

Blu-ray

DVDs just can't keep up with the latest demands for high-capacity storage, but a solution is on the horizon and, as Mike James explains, it's all about the colour blue

CDs and DVDs have become the universal means of carrying software, data and digital music and video around. However, even DVDs now struggle to fulfil the storage requirements of high-definition video, and they certainly lack the capacity to back up today's huge hard disks. Backing up a 500GB drive would take over 100 single-layer DVDs.

A new optical disc that meets the demands of the latest technology is needed. Various solutions are waiting in the wings, but one is about to arrive in the UK. Blu-ray is a new optical disc with the kind of capacity we need both for general data and high-definition video. So what's the secret to the incredible increases in capacity? The answer, surprisingly, is the colour blue.

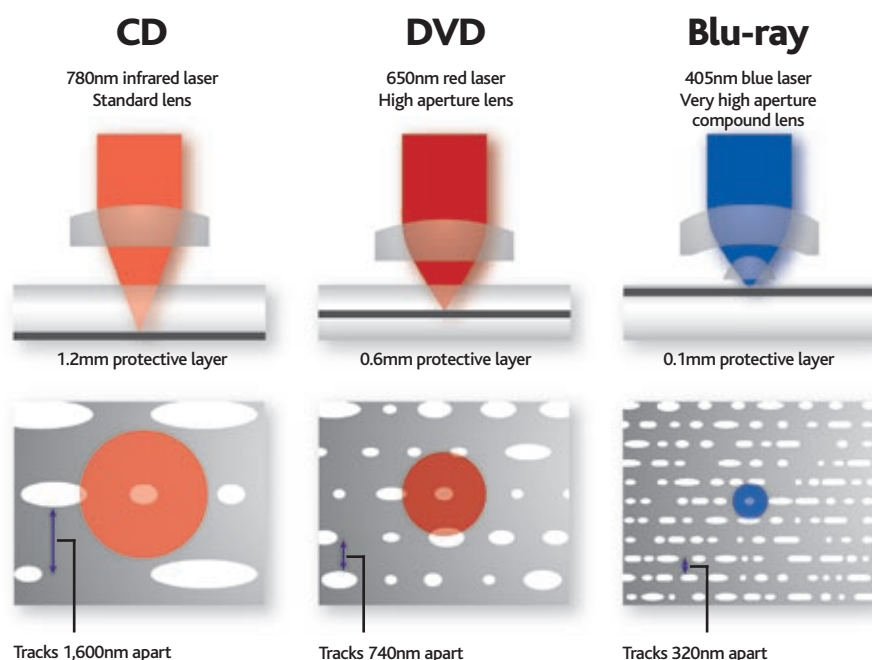
LET THERE BE LIGHT

The key technology in all optical storage is the laser. A CD stores data as a pattern of 'pits' or small depressions in a plastic surface that's backed by a reflective layer. As the disc spins a laser shines on the disc and is either reflected back if it hits a smooth mirror-like area or not if it hits a pit. An optical sensor picks up the flashing of the reflected beam and allows the pattern of pits to be converted into the familiar zeros and ones of binary data.

In the case of a writable CD, the physical pits are replaced by dye that changes colour when a higher-powered laser is used to write the disc. Again, the general principle is the same: the reading laser is either reflected or not reflected due to an opaque spot on the disc.

While the theory behind optical discs sounds straightforward, making it work is tricky. The pits must be very small in order to pack a worthwhile amount of data on a disc, and the disc has to spin as quickly as possible to provide a data transfer rate suitable for digital audio or video. As the pits are so small, the laser must be focused to an extremely

LASERS USED BY DIFFERENT OPTICAL DISCS



When the laser uses a shorter wavelength – as with Blu-ray, where the wavelength is 405nm, compared to a CD's 780nm – the spot is smaller, which means that the pits can be smaller and the tracks closer together

sharp point. What's more, as discs are liable to wobble and change the distance from the laser, a CD drive must be capable of dynamic focusing to maintain a sharp beam and dynamic tracking to keep the laser on the track of pits it is following. Even with all this clever engineering, CD drives rely on powerful error detection and correction codes to make up for bits they can't read.

IT'S THE PITS

So how do you improve optical storage? In theory the answer is simple: you make the pits smaller to pack more on the same-sized disc. This also has the benefit of increasing the rate at which data can be read or written without changing the spin rate of the disc.

Unfortunately, reading smaller pits requires an even more sharply focused and guided laser beam, and as the laser spot gets really small a physical effect known as diffraction becomes significant (see 'The Physics of Waves', right). Diffraction causes light to spread out, making the spot swell in size. The degree of swelling depends on the optics (specifically the 'numerical aperture' of the lens) and the colour (wavelength) of the laser light used.

A standard CD uses an infrared laser with a wavelength of 780nm, which produces a spot smaller than 2 micrometres. With a spot of this size, tracks can be around 1.6 micrometres apart without neighbouring data interfering significantly with the track that's being read. DVDs also use a red (650nm) laser, but this is focused down to a spot roughly 1.5 micrometres or 1,500nm in size, thanks to a lens with a larger numerical aperture.

BLU-RAY DRIVES

The technology industry is driving Blu-ray mainly as a medium for high-definition movies and interactive graphics. Consequently, the first drives to appear have been home entertainment devices designed to replace DVD players and recorders.

Blu-ray players typically offer more facilities than DVD players. For example, they may be intelligent enough to connect to the internet and download additional content and interactive features. Blu-ray video recorders are designed to allow on-disc editing and the creation of playlists.



BenQ demonstrated a Blu-ray drive for PCs at Computex 2005, which it plans to launch in 2006. The BW1000 writes Blu-ray discs at 2X, DVD+R/-R at 12X, DVD+R/-R DL at 4X and DVD+RW/-RW at 4X.



The lens on a DVD reader allows tracks to be packed twice as close as those on a CD

This allows adjacent tracks to be packed 740nm apart, which is twice as close as those on a CD, and pits to be proportionately smaller. The pits are not circular but more like dashes, and the shortest DVD pit is 400nm long. Thanks to both these features a single-layer DVD can store roughly seven times as much data as a single-layer CD.

A DVD provides about as much storage capacity as is possible using a red laser. Blu-ray's production depended on the development of a low-cost blue laser. Blu-ray uses a blue laser with a wavelength of 405nm focused down to a spot roughly 0.6 of a micrometre or 600nm in diameter, allowing for smaller pits and tracks that are an amazing 0.32 of a micrometer apart. As a result of using a blue laser, a single-layer Blu-ray disc, which is roughly the same size as a DVD, can hold up to 27GB of data. A double-layer Blu-ray disc can store up to 54GB and there are plans to develop a disc with twice that capacity.

These higher capacity discs use multiple recording layers, although this makes it harder to build a drive that can write as well as read data. Blu-ray or a similar technology is expected to replace DVDs for distributing movies because it can store 13 hours of standard video or two hours of high-definition TV.

Blu-ray has a higher data transfer rate than DVD – 4.5MB/s compared to DVD's typical 1.25MB/s – simply because the bits are closer together. A Blu-ray disc can record 25GB of material in just over an hour and a half.

THICK AND THIN

One potential problem with Blu-ray is that the data is stored on a layer with only a thin 0.1mm protective coating. DVDs have a much thicker 0.6mm protective layer. Blu-ray discs need a thinner protective layer so they can use a lens with a higher numerical aperture and minimise the effect of any misalignment between the disc and the laser. However, the thin protective coating makes Blu-ray discs less robust than DVDs, particularly as smaller pits and closer tracks make Blu-ray discs more sensitive to scratches and contamination.

Early Blu-ray discs had to be used in a cartridge, rather like early CDs, but TDK recently invented a coating that's hard enough to allow the discs to be used without an outer case. As a result, the most recent Blu-ray drives don't use special caddies and can be treated just like DVDs.

Blu-ray already has a range of pre-defined writable formats, including BD-R for data storage, BD-RW for rewritable data storage and BD-RE for HDTV recording. BD-ROM is the read-only disc format for pre-recorded content.

THE PHYSICS OF WAVES

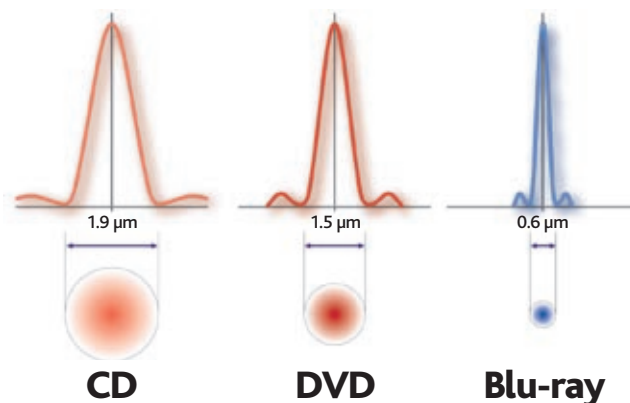
Light is a wave and shares the characteristics of other types of wave. Like waves in water, light has a wavelength, which is the distance between two wave crests. As light is an electromagnetic wave its 'crests' are fluctuations in the strength of an electromagnetic field. The wavelength, which is measured in nanometres ($1/1,000,000,000$ ths of a metre) determines the colour of light.

Like other waves, light behaves strangely when navigating objects that are the same sort of size as its wavelength. It stops moving in straight parallel beams and starts to bend round corners and spread out, an effect known as diffraction. Most of the time we don't notice this, but in the microscopic world of optical drives diffraction is a real problem.

As the laser moves towards the blue end of the spectrum the focused spot size decreases.

For lenses, the degree of diffraction depends on the wavelength of the light and the numerical aperture (NA) of the lens. The beam size (d)

BEAM SIZES OF LASERS



depends on the aperture and wavelength (λ) according to the equation:

$$d = k \cdot \lambda / NA$$

where k is a constant. Shorter wavelengths of light and lenses with higher numerical apertures therefore produce sharper beams of light.

Blue light has a wavelength of just 400nm and this, combined with a lens with a high NA, enables a Blu-ray disc to store data using pits that are just 0.6 micrometers in diameter.

DOUBLE STANDARDS

Whether or not Blu-ray becomes as ubiquitous as the DVD depends largely on market forces. As with all new technologies there are rivals for the crown of *de facto* standard, and Blu-ray's main rival is called HD-DVD. An HD-DVD is more like a regular DVD, with a thick protective layer, and can be made in a standard DVD pressing machine.

The disadvantage is that the thicker protective layer causes more optical problems and necessitates the use of a lower-aperture lens, which means HD-DVD can't reach the same storage capacities as Blu-ray. Currently a single-layer HD-DVD can store 20GB and a double-layer disc can store 30GB.

Yukinori Kawauchi, head of next-generation DVD development at Sony (one of the main backers of Blu-ray) has said the Blu-ray camp is open to discussion on creating a unified standard with HD-DVD, but this looks increasingly unlikely. It may be unnecessary, though, as prototype Blu-ray drives that can also read DVDs have been built, which suggests that a dual-format Blu-ray/HD-DVD drive should also be possible.

The Blu-ray standard is still under development. TDK recently revealed that using a more powerful laser and a slightly different recording medium could boost Blu-ray's capacity to 100GB per disc and double the data transfer rate to 72Mbit/s.

In the longer term, optical storage has the potential to pack more bits per inch than any other technology, especially if holographic

and other techniques using phase recording become economically viable. In the immediate future the only hope for a half-terabyte optical drive is to move from a blue laser to an ultraviolet laser, which has a shorter wavelength than blue light and so can be focused to an even smaller spot. Pioneer is working on an ultraviolet system that promises to pack 500GB on a single disc, but there are no estimates on how long it might be before a product is announced. **CS**

FURTHER INFORMATION

The Blu-ray disc association
www.blu-raydisc.com

Blu-ray news, FAQs and products
www.blu-ray.com

Competing optical technologies
www.discronics.co.uk/technology/hddvd

For a detailed technical specification of Blu-ray, see:
www.blu-raydisc.com/assets/downloadablefile/general_blu-raydiscformat-12834.pdf

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